Appendix G
Climate Change

August 2016

Overview

Throughout eastern Wyoming, a number of resources could be affected by alterations in future weather and land-use conditions resulting from possible changes in the overall climate of the region. Meteorological data collected throughout the world during the last 50 years show strong indications of a warming planet. Other environmental data collected from oceans, wetlands, forests, and the polar regions (associated with ice pack extent, thickness, and melting) corroborate the global warming trend. It is well known that certain gases in the atmosphere allow short-wave radiation from sunlight (visible light, ultraviolet, near infrared) through the atmosphere. These gases include CO_2, methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulfur hexafluoride (SF_6), VOCs, water vapor, and other trace gases. When the sun's radiation strikes Earth's surface, heat is generated in the form of infrared radiation. These same gases act to absorb longer wave infrared radiation, resulting in a warming of the atmosphere. This phenomenon is known as the "greenhouse effect," because these gases, referred to as greenhouse gases (GHGs), act to trap heat in the atmosphere in a similar manner as a greenhouse.

Throughout Earth's history, the proportions of the major constituents of the atmosphere (oxygen and nitrogen, which make up 99 percent of the atmosphere) have changed somewhat due to natural and geogenic processes. The concentrations of minor constituents such as CO_2, CH_4, N_2O, and water vapor have also varied somewhat throughout history. Since the advent of the Industrial Revolution in the 1700s, fossil fuels (coal, oil, and natural gas) have been used for heat and power generation throughout the world. This has resulted in increases in the concentrations of GHGs, compared to pre-industrial concentrations, as estimated using long-term historical records of ice-core samples. During the last 50 years, the rate of this increase in GHG concentrations, especially CO_2, has shown a dramatic upward trend, likely due to the increased burning of fossil fuels brought on by larger populations demanding more energy throughout the world, especially in Asia and other newly developing countries. The increases in CO_2 are due to the use of fossil fuels and certain changes in land use. The major human activities that cause increases in CH_4 are coal mining and releases of natural gas from oil and gas operations, and the major human activities that cause increases in both CH_4 and N_2O include animal manure management, agricultural soil management, sewage treatment, and combustion of fossil fuels in stationary and mobile sources (IPCC, 2014).

Indicators

In the air quality analysis area, most GHG emissions, primarily in the form of CO_2, result from the combustion of fossil fuels for oil and gas drilling and production operations and transportation. Energy demand, which is the main driver for natural gas development, is influenced by regional and national population growth, economic development, and seasonal weather conditions. CH_4 emissions also result from the development of fossil fuel resources, landfills, and agricultural and livestock activities.

Current Conditions

Throughout the Mountain West, including eastern Wyoming, numerous types of activities and actions result in GHG emissions, with the largest contributor being the combustion of fossil fuels in power plants; on-road and off-road vehicles; drilling engines, pumps, and compressors used in oil and natural gas development; and construction equipment. In addition to direct GHG emissions from these activities, indirect GHG emissions and other factors potentially contributing to climate change include electricity generated outside the analysis area, land-use changes (e.g., converting forested areas to agricultural use), and soil erosion.

Trends

According to climate change researchers, the effects of climate change are expected to vary by region, season, and time of day. Computer model forecasts indicate that increases in temperature will not be evenly or equally distributed, but are likely to be accentuated at higher latitudes. Warming during winter is expected to be greater than during the summer, and increases in daily minimum temperatures are more likely than increases in daily maximum temperatures. Within a given region, increasing temperatures also could affect the amount of water vapor in the atmosphere, the timing and amount of precipitation, the intensity of storm systems, snow melt, and soil moisture. All of these factors can affect climate, day-to-day weather conditions, plant physiology, and air quality.

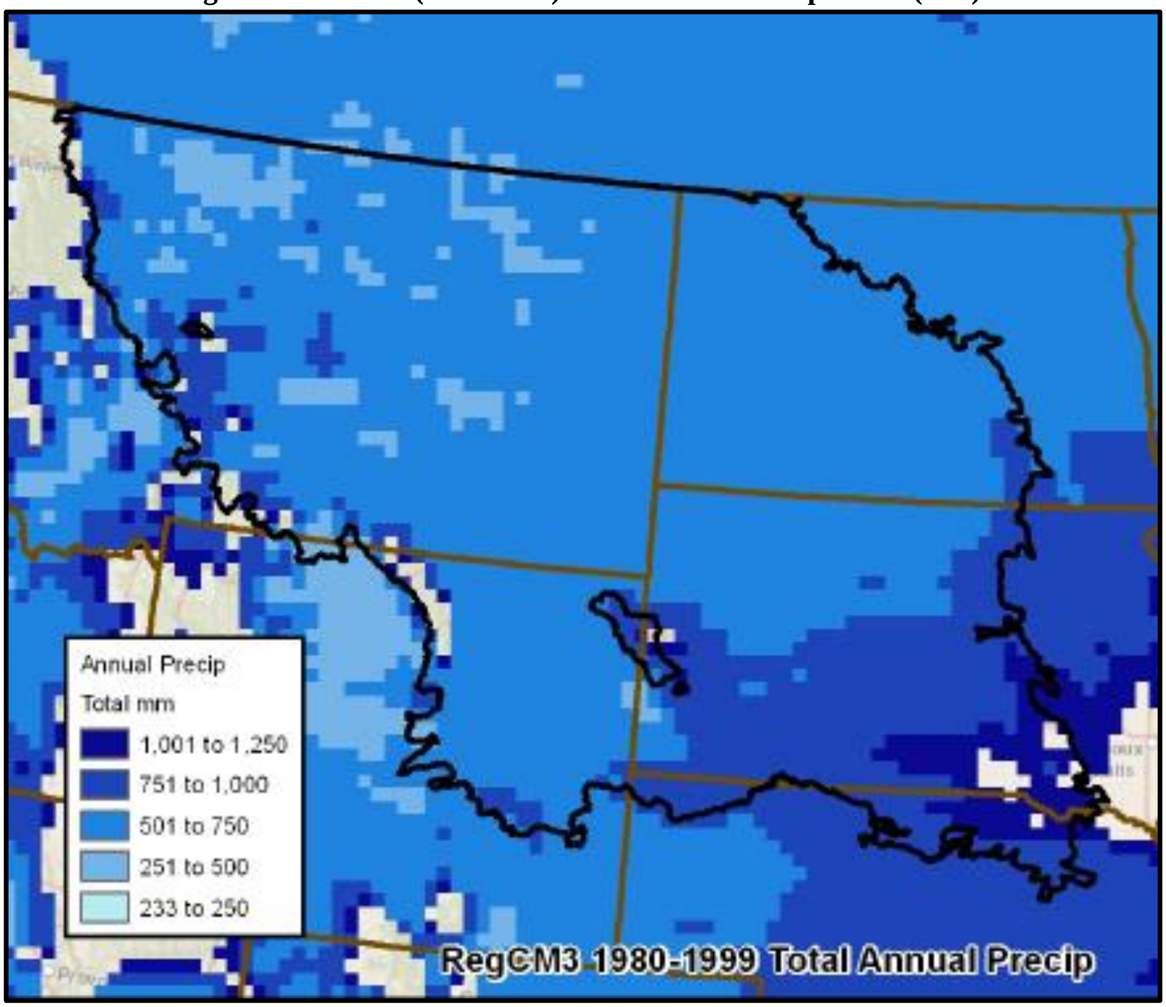
Based on research compiled for the International Panel on Climate Change Fifth Assessment Report, (IPCC, 2014) potential effects of climate change on resources in the affected environment are likely to be varied. Within North America, the report specifically forecasts that: warming in western mountains is projected to cause decreased snowpack, more winter flooding and reduced summer flows, exacerbating competition for over-allocated water resources; in the early decades of the century, moderate climate change is projected to increase aggregate yields of rain-fed agriculture by 5 to 20 percent, but with important variability among regions; major challenges are projected for crops that are near the warm end of their suitable range or which depend on highly utilized water resources; cities that currently experience heat waves are expected to be further challenged by an increased number, intensity and duration of heat waves during the course of the century, with potential for adverse health impacts; and coastal communities and habitats will be increasingly stressed by climate change impacts interacting with development and pollution.

Specific modeling and/or assessments of the potential effects for the State of Wyoming currently do not exist; however, there are downscaled models that have been applied for the area such as a Rapid Ecoregional Assessment (REA) and the 2014 National Climate Assessment (GCRP, 2014).

In 2012, the Northwestern Plains REA presented the results of the climate change analysis for this ecoregion. The analysis is presented as a series of figures generated using the RegCM3 15-km pixel regional climate change model data. The figures that are included depict the current or baseline period (1980 to 1999).

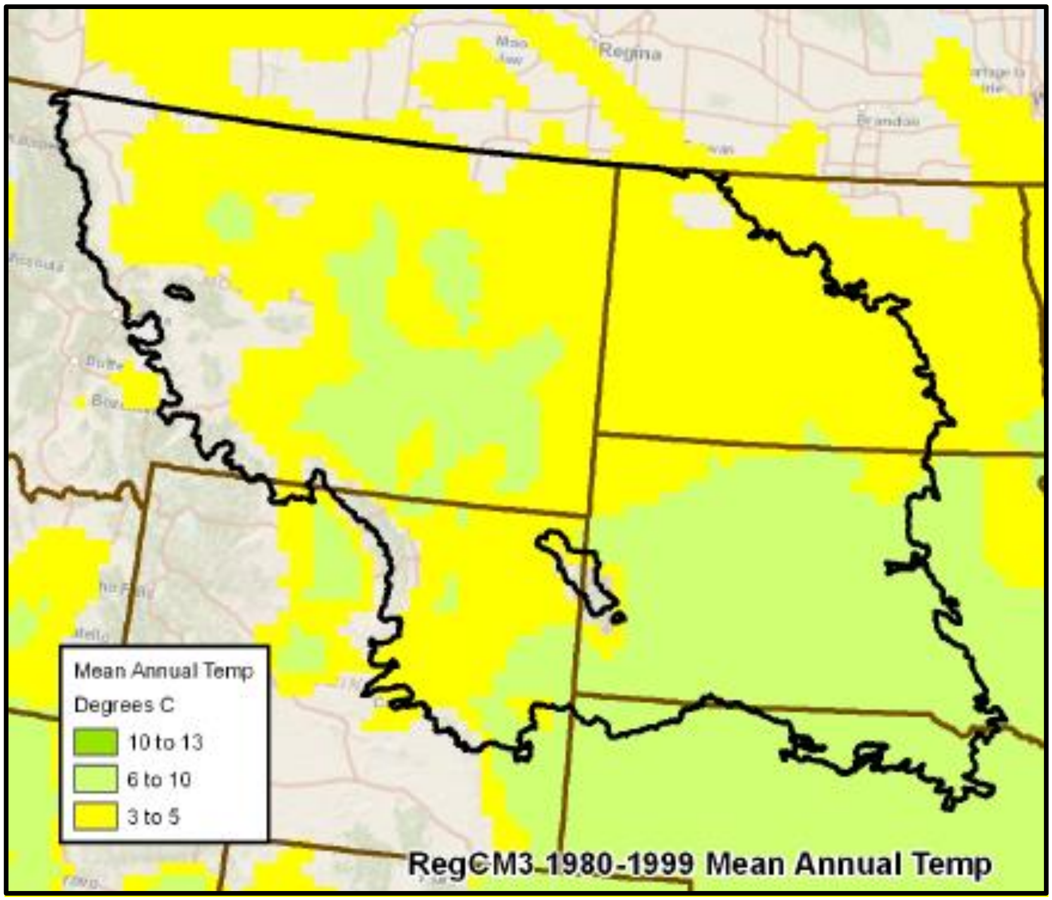
The general precipitation pattern is presented on Figure 1. The general annual average precipitation pattern for the Northwestern Plains ecoregion is a trend of increasing precipitation from the northwest to the southeast. This trend is not present in the November to February period and is less apparent during the warm rainy season in May and June. The Powder River Basin southwest of the Black Hills is another exception as it is relatively drier than the southeastern area of the ecoregion.

Figure 1. Current (1980-1999) Total Annual Precipitation (mm).



The mean annual temperature for existing climate pattern in the Northwestern Plains is presented on Figure 2. The climate change model indicates that the southeastern corner of the Northwestern Plains is generally warmer than the rest of the ecoregion. The model shows an exception as an area in south central Montana that is slightly warmer than the surrounding areas during the November to February season.

Figure 2. Current (1980-1999) Mean Annual Temperature (°C).



All of North America is likely to experience an increase in average temperature during the next 100 years, and annual mean warming is likely to exceed global mean warming in most areas (IPCC, 2014). Temperatures are projected to increase substantially by the end of this century (GCRP, 2009). Summer temperatures are expected to increase between approximately 7°F and 10+°F by 2080 to 2099. Overall, temperature in the region is projected to increase between 2.5°F to more than 13°F compared to the 1960 to 1979 baseline, depending on future GHG emissions (GCRP, 2009). This range of temperature increase reflects the current uncertainty in climate change modeling and represents the likely range of model projections, although lower or higher outcomes are possible.

Increasing temperatures are likely to contribute to increased evaporation, drought frequencies, and declining water quantity. The warming of lakes and rivers will adversely affect the thermal structure and water quality of hydrological systems, which will add additional stress to water resources in the region (IPCC, 2014). The area depends on temperature-sensitive springtime snowpack to meet demand for water from municipal, industrial, agricultural, recreational uses and BLM-authorized activities. The U.S. Geological Survey (USGS) notes that mountain ecosystems in the western U.S. are particularly sensitive to climate change, especially in the higher elevations, where much of the snowpack occurs, which have experienced three times the global average temperature increase over the past century. Higher temperatures are causing more winter precipitation to fall as rain rather than snow, which contributes to earlier snowmelt. Additional declines in snowmelt associated with climate change are projected, which would reduce the amount of water available during summer (GCRP, 2009). Rapid spring snowmelt due to sudden and unseasonal temperature increases can also lead to greater erosive events and unstable soil conditions.

Increases in average summer temperatures and earlier spring snowmelt are expected to increase the risk of wildfires by increasing summer moisture deficits (GCRP, 2009). Studies have shown that earlier snowmelts can lead to a longer dry season, which increases the incidence of catastrophic fire (Westerling et al., 2006). Together with historic changes in land use, climate change is anticipated to increase the occurrence of wildfire throughout the western U.S. The latest GCRP assessment (GCRP, 2014) predicts that temperatures and precipitation over the region will continue to increase, especially if GHG emissions remain high. In addition, the assessment predicts that the frequency of extreme weather events such as heat waves, droughts, and heavy rainfall will also increase and may affect water resources, forests and wilderness areas, agricultural and ranching activities, and human health.

There is evidence that recent warming is impacting terrestrial and aquatic biological systems, with higher temperatures leading to earlier timing of spring events such as leaf-unfolding, bird migration, and egg-laying (IPCC, 2014). The range of many plant and animal species has shifted poleward and to higher elevation, as the climate of these species' traditional habitat changes. As future changes in climate are projected to be even greater than those in the recent past, there will likely be even larger range shifts in the coming decades (Lawler et al., 2009). Warming temperatures are also linked to earlier "greening" of vegetation in the spring and longer thermal growing seasons (IPCC, 2014). In aquatic habitats, increases in algal abundance in high-altitude lakes have been linked to warmer temperatures, while range changes and earlier fish migrations in rivers have also been observed. Climate change is likely to combine with other human-induced stress to further increase the vulnerability of ecosystems to other pests, invasive species, and loss of native species. Climate change is likely to affect breeding patterns, water and food supply, and habitat availability to some degree. Sensitive species, such as the Greater Sage-Grouse, which are already stressed by declining habitat, increased development and other factors, could experience additional pressures as a result of climate change.

More frequent flooding events, erosion, wildfires and hotter temperatures all pose increased threats to cultural and paleontological sites and artifacts. Heat from wildfires, suppression activities and equipment, as well as greater ambient daytime heat can damage sensitive cultural resources. Similarly, flooding and erosion can wash away artifacts and damage cultural and paleontological sites. However, these same events may also uncover and lead to discoveries of new cultural and paleontological localities.

Climate change also poses challenges for many resource uses on BLM-administered land. Increased temperatures, drought and evaporation may reduce seasonal water supplies for livestock and could impact forage availability. However, in non-drought years, longer growing seasons resulting from thermal increases may increase forage availability throughout the year. Shifts in wildlife habitat due to climate change may influence hunting and fishing activities, and early snowmelt may impact winter and water-based recreational activities. Drought and resulting stress on vegetation is likely to increase the frequency and intensity of mountain bark beetle and other insect infestations, which further increases the risk of fire and reduces the potential for sale of forest products on BLM-administered lands.

A variety of activities currently generate GHGs. Fuels combustion, industrial processes and any number of other activities on public lands result in direct emissions of GHGs. Direct emissions include those related to current and ongoing oil and gas and other minerals development, fire events, motorized vehicle use (e.g., off-highway vehicles), livestock grazing, facilities development, and other fugitive emissions. Indirect GHG emissions include the demand for electricity generated outside the area. Contributions to climate change also result from land use changes (conversion of land to less reflective surfaces that absorb heat, such as concrete or pavement), and soil erosion (which can reduce snow's solar reflectivity and contribute to faster snowmelt).

Climate change science and projections of climate change is a continually growing and emerging science. Additional and recent information on climate change and regional projections of climate change can be found through the U.S. Global Change Research Program (http://www.globalchange.gov/) and the Intergovernmental Panel on Climate Change (http://www.ipcc.ch/).

Several federal initiatives have been launched to improve the ability to understand, predict, and adapt to the challenges of climate change. The Secretary of the Interior signed Secretarial Order 3289 on February 22, 2010, establishing a Department-wide, scientific-based approach to increase understanding of climate change and to coordinate an effective response to impacts on managed resources. The order reiterated the importance of analyzing potential climate change impacts when undertaking long-range planning issues, and also established several initiatives including the development of eight Regional Climate Science Centers (DOI, 2010). Regional Climate Science Centers would provide scientific information and tools that land and resource managers can apply to monitor and adapt to climate changes at regional and local scales. The North Central Climate Science Center was established in 2011.

Given the broad spatial influence of climate change which requires response at the landscape-level, the U.S. Department of the Interior (DOI) also established Landscape Conservation Cooperatives which are management-science partnerships that help to inform management actions addressing climate change across landscapes. These Cooperatives are formed and directed by land, water, wildlife and cultural resource managers and interested public and private organizations, designed to increase the scope of climate change response beyond federal lands.

Other federal initiatives are being implemented to mitigate climate change. The Carbon Storage Project was implemented to develop carbon sequestration methodologies for geological (i.e., underground) and biological (e.g., forests and rangelands) carbon storage. The project is a collaboration of federal agency and external stakeholders to enhance carbon storage in geologic formations and in plants and soils in an environmentally responsible manner. The Carbon Footprint Project is a project to develop a unified GHG emission reduction program for the DOI, including setting a baseline and reduction goal for the Department's GHG emissions and energy use. More information about DOI's efforts to respond to climate change is available at: www.doi.gov/whatwedo/climate/index.cfm.

In addition to DOI's efforts to address this issue, the EPA has undertaken a number of regulatory initiatives in recent years to reduce GHG emissions. For over 20 years, the EPA has developed approaches and strategies for reducing GHG emissions from natural gas operations through its Natural Gas Star Program (EPA, 2014). This program has provided recommendations for capturing or reducing fugitive emissions of VOCs, including hazardous air pollutants (HAP), as well as GHG's such as methane. In 2009, a finding was made under the Clean Air Act identifying the key constituent gases that threaten public health and welfare and contribute to climate change. An initiative was developed for mobile sources by setting engine and fuel standards to cut GHGs and fuel use for new motor vehicles, and the implementation of a renewable fuel standard aimed at decreasing oil imports and reducing GHGs.

Another initiative addresses stationary sources to limit GHGs for power plants and other large industrial facilities. The EPA also initiated a national GHG emissions reporting program for large emitters. In 2012, EPA finalized regulations to reduce pollution from the oil and natural gas industry which is expected to result in substantial reductions in VOC emissions, air toxics, and CH_4, an important GHG (EPA, 2012). Most recently, EPA extended the rule to mandate control requirements for hydraulically fractured oil wells (EPA, 2015). In addition to requiring reduced emission completions (or "green completions") of oil wells, the rules also mandate that developers find and repair leaks, limit emissions from new and modified pneumatic pumps, and limit emissions from several types of equipment used at natural gas transmission compressor stations and at gas storage facilities, including compressors and pneumatic controllers. These actions, initiatives, and regulations will impact activities, especially those related to oil and natural gas development, in an overall effort to balance growth in resource development with continued reductions in key GHG emissions.

Intergovernmental Panel on Climate Change (IPCC). 2014. "Climate Change 2014: Synthesis Report. Of the Fifth Assessment Report of the Intergovernmental Panel on Climate Change" [Core Writing Team, Pachauri, R.K and Meyer, L. (eds.)]. Intergovernmental Panel on Climate Change, Geneva, Switzerland, 139 pp.